U.S. Nat'l Oceanic & Atmos Admin.

VOLUME 10

NUMBER 1

JANUARY/FEBRUARY, 1980

NOAA

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Glass mustard bottle retrieved from the wreck of the U.S.S. Monitor *in the NOAA-sponsored archaeological expedition* *(See story p. 24).*

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Albert Mark
Director, Public Affairs

Anna V. Felter
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NOAA (USPS 417-370) is published quarterly by the Office of Public Affairs, National Oceanic and Atmospheric Administration, Rockville, Md. 20582, to acquaint readers with the policies and programs of the agency. The Secretary of Commerce has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through December 31, 1982.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 29492. Annual subscription $7.50, $1.90 additional for foreign mailing. Single copy $1.90, $2.40 single copy foreign. Controlled circulation postage paid to Finance Dept., USPS Washington, D.C., 20260.

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Photo: National Park Service

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Making It Happen

More than ten years ago, when the new agency that came to be the National Oceanic and Atmospheric Administration was under consideration, a member of Congress was quoted as saying that forming such an agency would be like "tying a bunch of cats together by their tails." So many components—some new, some almost as old as the country itself—represented too wide a variety of responsibilities and disciplines, he thought, ever to become a smoothly operating entity.

The prediction proved incorrect. Instead, those who appreciated the enormous potential of the oceans and understood the inexorable link between the oceans and the atmosphere proved to be right. As we launch NOAA's tenth anniversary year, NOAA and its employees have a splendid record of accomplishment, and the many parts are working together well. This is evidenced by the fact that NOAA has received major new responsibilities—from satellites to seabed minerals—since its creation.

The work of one component often reinforces and strengthens that of another. A major example is the recent Bay of Campeche oil spill response, which brought together at least six NOAA components into a cohesive team effort. Indeed, scarcely a day goes by but I see another such instance of mutual effort and assistance—instances such as the National Ocean Survey and the Office of Coastal Zone Management cooperating on storm evacuation maps, and other major coastal hazards initiatives—the National Environmental Satellite Service providing frontal sketch charts that Sea Grant rapidly distributes to fishermen—the National Weather Service and the National Marine Fisheries Service joining in to refine and expand services provided to the fishing industry—the Environmental Research Laboratories and Environmental Data and Information Service linked inextricably in climate research—and so on. Mutually beneficial symbiotic relationships that could not have been foreseen a decade ago are multiplying and thriving.

NOAA's tenth anniversary year gives us the opportunity to focus public attention on the accomplishments of the agency and of its many components—accomplishments which demonstrate that the logic behind NOAA's formation is borne out in process and in product. In short, NOAA runs smoothly and well. That it does is due in great measure to the imagination and dedication of you, NOAA employees whose dedication and talents have made our success story possible. It is appropriate, at the opening of NOAA's second decade, to salute you, both for what you have done and for what you will do to make NOAA's future years even more noteworthy in the annals of Federal achievements.

The Ixtoc I oil spill in the Bay of Campeche stimulated a massive U.S. response effort including a team representing at least six NOAA components.

Photo: Coast Guard

Photo: NOAA

IXTOC-I: Six Perspectives

By CARL POSEY

SUMMER 1979. It is a summer of uncertainties.

Skylab's dying orbit puts the reentering derelict somewhere between 50 degrees north and 50 south of the equator, over a footprint several thousand miles long.

The hurricane season opens. Atlantic cities are overdue for a big one.

But in Mexico's Bay of Campeche, cocky optimism reigns among technicians aboard the Sedco 135 submersible oil rig. They are drilling Ixtoc-I, an offshore well in one of the planet's new but already legendary fields. More than 50 wells punched, every one a producer. Not much room for uncertainty here.

Ixtoc-I drilling began late in November 1978. By Memorial Day, the well is more than two miles deep. Drilling is proceeding routinely.

JUNE 1. Luck runs out. Circulation of the lubricant drilling mud chokes abruptly. The drill bites through a fractured stratum. Mud squirts into the crack. Technicians restore drilling-mud circulation late in the day.

JUNE 2. About 75 feet deeper, another soft layer is pierced. The entire drill chain drops several feet, and drilling-mud circulation is again lost. After monitoring the well for signs of pressure for more than 10 hours, the drillers begin removing the drill bit and pipe from the hole for inspection. Well pressure is checked every 900 feet and new mud is pumped into the hole to displace the removed pipe.

JUNE 3. The thick metal drill collars, just above the bit, reach the top of the hole. Suddenly, mud bursts from the hole around the drill pipe aboard the rig, and pressure soars. On the seafloor, a pressure-activated blowout preventer fails to cut through the drill collars' heavy metal and seal the drill pipe. On the rig, the sudden surge of mud mangles the threading on a drill pipe, jamming the chain of pipe in place. Now it can neither be withdrawn nor reinserted.

Oil and gas follow drilling mud onto the rig. The wild torrent of petroleum bursts into a plume of fire that will burn until October.

Fire destroys most gear on Sedco 135. As the drill chain crumbles into the sea, the rig is towed away and scuttled 200 miles offshore. Oil, tens of thousands of barrels a day, spews from the seafloor into the Gulf of Mexico, the worst oil spill on record.

As the oil drifts inexorably northward toward the Texas coast, it draws an unprecedented response from the U.S. Government.

Debbie Payton

She never sees the Alamo. She spends the week in San Antonio, Tex., the seeming eternity in Corpus Christi, as handmaiden to The NOAA Model, a mathematical creature whose integrated imaginings simulate the trajectories of oil spilled upon the sea. Only a few days after the spill, Debbie Payton and her colleagues begin feeding information to The Model. Its pronouncements play back from the big CDC 6600 computer at NOAA's Boulder, Colo., laboratories through a terminal hooked up to a telephone in a motel-room command center.

To Payton, a mathematician and a degree candidate at the University of Washington, "The model's really just a way of managing data." Nothing mysterious about it. "A lot of pieces go into it," she explains.

So, The NOAA Model that begins to appear in the national press is a collection of smaller models—some diagnostic, some prognostic—sets of mathematical equations that can accept the quantities of the real world. "The numbers can translate into little arrows," Payton says. "Winds can fit into vectors. We can add in the observed oil conditions."

Dr. Jerry Galt is the father of this family of models. Throughout the summer, he flies in from Seattle to make some fine adjustment, add some fresh insight. From early June, Galt and his colleagues focus The Model upon the oil in Campeche Bay. They assume it will float on and on, evading containment at the well site, and patch in the skimpy information available on winds and currents over the Gulf of Mexico. Devouring new information, The Model grows "smarter."

"The Model that went down to San Antonio and Corpus wasn't the one we wound up with," Payton says. "Jerry rewrote it about two weeks into the spill."

Photo: NOAA

Debbie Payton, mathematician and collector of oil samples . . . handmaiden to The NOAA Model.

Photo: NOAA

The NOAA Buffalo *photoplane casts a shadow over ugly oil swath on a Mexican beach 60 miles south of Brownsville, Tex.*

Photo: Coast Guard

Photo: Coast Guard

Photo: Coast Guard

Texas waters (top photos) . . . Diagonal pattern of booms in inlet was planned to permit fishermen to transit the cut while keeping the oil from passing through into the lagoon behind Padre Island; commercial skimmers working for the Coast Guard trap and capture some of the oil from the slick (foreground).

Mexican waters (bottom photo) . . . Gas fire burns fiercely atop blowout, at right, as massive oilslick envelops ships, barges, and drill platforms at the spill site.

As the spill progresses northward, The Model is refined to give a closeup picture of the Texas coast. "The map in the model," Payton explains, "is made by taking a chart and overlaying a grid. So, to zoom in we just grid a larger-scale chart. Right now, there are three maps in The Model. One of the whole Gulf, and closeups of the Corpus Christi and Brownsville areas."

The keepers of the Model are forced into a diurnal routine that skips weekends and holidays. "During the day we helped take data, current measurements, oil mapping, and so forth," recalls Payton. "After the evening meeting, when we had information on what was seen that day, we ran the model. We get better turnaround from the computer because it's less busy at night."

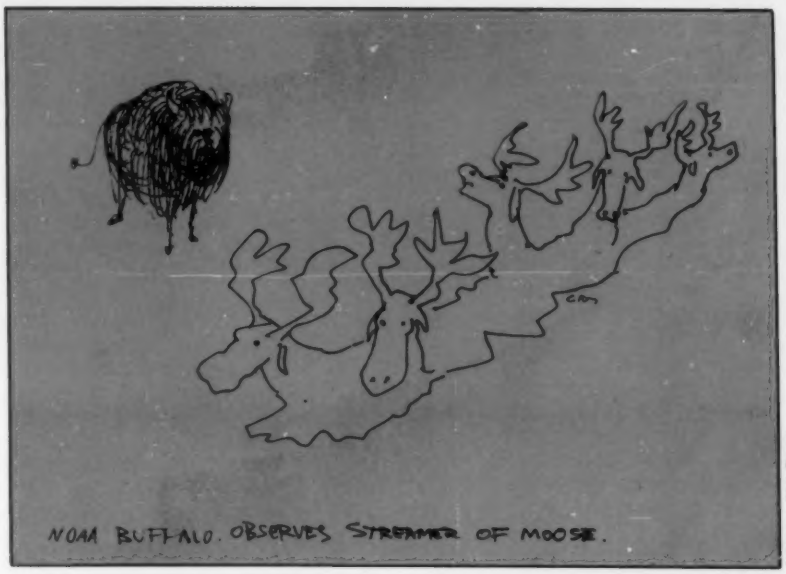
Feeding the Model and receiving its pronouncements takes 4 hours, most of it spent handshaping information into digitally palatable form. The run itself takes about 20 minutes on the Boulder computer.

This time-obliterating routine is broken for Payton in early August when she boards the Coast Guard cutter *Valiant* as part of the scientific party. Using helicopters and launches, "we got the first samples close to the well," she says. Her presence on board was another kind of achievement. "The skipper said it was the first time any of these cutters has had a woman on it for a week-long voyage."

Though a prisoner of The Model for 4 months, toward the end Payton is pleased with her mathematical partner. "We were very proud of the model," she says. "It had never been used over such a long period of time, and it performed very well. About two-thirds of the way through, when the pressures eased a little, we began experimenting with it, running it backwards to check its performance more closely."

But in early July, when the Federal response to the oil spill has barely begun, there is uncertainty about the NOAA Model's grasp of the problem. To the practical-minded individuals who must contain spills, there is something insubstantial about a bunch of equations stored in a computer a thousand miles away. The Model, after all, is still experimental, a research device developed as part of NOAA's efforts to solve Alaska's future problems with oil development along the outer continental shelf. Reconnaissance flights show the oil way down by Tampico. No way it will do what The Model predicts . . . .

The Model persists: oil will touch shore at the 25th parallel of latitude by the end of July.



Cartoon: Carl Posey

Rich Hayes

Another endless day aboard the NOAA *Buffalo* reconnaissance plane . . . Rich Hayes, still in his tangerine flight suit, is ready for a beer, a bath, and a shave, luxuries that will follow the evening debriefing.

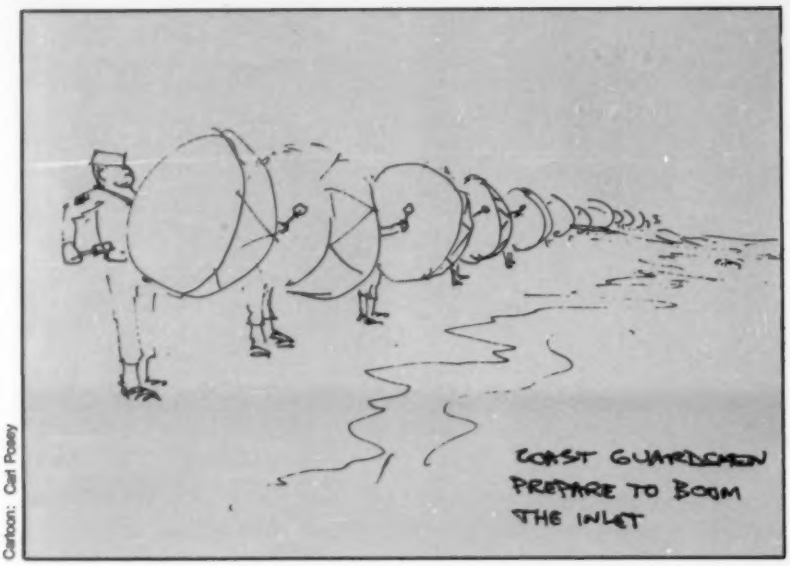
The *Buffalo* has become a minor hero in the Campeche drama. It lacks the endurance of the Coast Guard C-130, carrying the Airborne Oil Surveillance System (AOSS). The *Buffalo*'s navigation gear is less precise, but the plane can fly low and slow, invaluable assets to the oceanographers mapping the oil.

Today, the *Buffalo* has flown a series of east-west tracks from the border southward to the 25th parallel, the demarcation line of Mexican airspace. They have been flying their pattern for 6-hour days rarely more than 800 feet above the sea, sometimes just 50 feet above the shoreline. Later, Navy P-3's, flying 12-hour missions, will pick up part of the aerial reconnaisance load.

Observers watch from the big fuselage windows beneath the *Buffalo*'s high wings, seated on oblongs of foam rubber and boxes. They are mapping the locations of the ugly brown emulsion, "mousse," and the discolored sea water, "sheen." At one point in the aerial reconnaissance, the entire Gulf to the south appears to be nothing but sheen, sheen out to the horizon, blending with the pale southern sky. Back in Corpus Christi, newpaper prose dilutes apprehension about the enemy approach, but from the low-flying *Buffalo*, the oil drifting north is an ominous sight indeed.

Remote-sensing has been Hayes' specialty for his decade with the Coast Guard. In July, he moves to the Corpus Christi command post to coordinate aerial reconnaissance.

"Our first priority," he remembers, "was to cover the area where some impact was likely. . . . It was as important at the beginning to know where the oil wasn't as to know where the oil was. We also needed to find the leading edge to use in the NOAA and Coast Guard



Cartoon: Carl Posey

models. And then we had to verify stories. We had a bunch of rumors coming up from the well site, and so we had to investigate them."

Hayes alternates his days between the long, dehydrating flights aboard the AOSS C-130 and the *Buffalo*. The C-130 is a cargo plane, the AOSS a sophisticated array of sensors reading out on consoles in the leviathan's belly.

The flights last 7 hours or more, and the observers have to stay "up" constantly, monitoring the instruments, recording positions and sightings. "You alert yourself by looking at the video display," says Hayes.

Everyone involved in the spill response says it's like doing live theater 12 hours a day. So, too, the AOSS flights.

The C-130 not only conveys instruments but also deploys some of them. Hayes has the AOSS plane dump into the water three buoys that can report their positions to passing NOAA satellites. Eventually, one of them confirms that the setting of the Gulf currents' northward have drifted to the south and east. By October, reversed currents will carry the buoy almost all the way back to IXTOC-1.

It is July 31. Hayes knows his report from the *Buffalo* will change the shape of the response. The C-130 has located the leading edge of the oil still nearly 200 miles south of the border and some 50 miles offshore. Hayes spots heavy oil along Mexican beaches and pancakes and mousse awash in the surf 50 miles south of Brownsville.

Is the oil weathered enough to be buoyant? Is it traveling north, submerged? No one knows. The only certainty: The Model was right; the oil has arrived as forecast.

Roger Madson

In the career of a Coast Guard Officer, there is nothing like the role of On-Scene Coordinator (OSC) for a major oil spill. The OSC leads the Federal response, guided by national and regional response teams. The OSC gathers together all the strands running out to hundreds of specialists thrown together by the threat of oil on a coastal reach. The OSC is a field commander.

"The job is unique," says Madson, one of several successive OSC's during the Campeche blow out. "You're not geared up like a fire department, where you have people and equipment always standing by. For the Federal response, all the people, finances, everything's on kind of a pick-up basis, and you're taking people out of the agencies' hides."

As July ends, Madson stands at a decision point as crucial as any he has faced in his 30-year career. Strike teams are already represented at the command post. They have attempted to define how many contractor people will be needed to help deploy containment gear and clean up oiled beaches. Now, after hearing Rich Hayes' report, Madson unleashes the poised Strike Team.

It is a large and expensive commitment. Equipment from around the country is stuffed into the C-130's fat fuselages, while other gear starts toward Texas on flatbed trucks. Miles of floating booms, skimmers, and other products of oil-spill containment know-how converge on Corpus Christi.

"Our priorities had already been established by a Regional Response Team meeting in New Orleans on July 13." recounts Madson, who was Regional Response Team chairman in Miami at that time. "We knew, for example, that we were just going to let the oil hit the barrier island beaches and clean it up there because it was impossible to attack it successfully at sea."

As the response unfolds, barriers are floated into place across the passes through the barrier islands at Brownsville and Port Mansfield. With tiny tar balls beginning to pepper South Padre Island, Madson, sensing mild panic, tells the press he thinks the worst is passed. "Of course, I was wrong," he says now. "It got much worse. I guess I didn't want to make an end-of-the-world kind of statement. And I guess I also wanted to protect Padre Island tourist interests, which were hit very hard long before there was any reason for them to be."

John Robinson

John Robinson casts a long, gaunt shadow across the Campeche response. He lives between high science and high pragmatism, applying basic research to solve immediate problems. His instincts have proven usually prescient. He won the Silver Medal for his role in anticipating the need for the outer continental shelf environmental assessment program and for bringing it to NOAA. Since then, he has been working on scien-

Photo: Coast Guard

tific support systems for spills of any hazardous material.

Robinson explains his effort in Corpus Christi: "We have two phases of scientific support." One is to mitigate the initial impact of the oil on beaches by keeping The Model up to date. "The other is damage assessment. We want to know what the environment is like before the oil gets here, and we want to be able to assess even the subtle effects of the oil after it begins to come ashore."

Robinson is Scientific Support Coordinator (SSC), the person on the OSC's staff who injects scientific information into the strategies of boom deployment and spill containment—data in currents, model predictions, chemical analyses, and a host of other crucial clues based on science, often threshold science. Three years ago no such job existed. It was born in the *Argo Merchant* spill and the Coast Guard's needs for certain types of scientific information.

In the Campeche spill, "There were two major unknowns. We weren't sure oil would float very far from the blowout. And we didn't know how much the Mexicans were recovering. The models had to assume zero containment.

"At first we didn't put a lot of trust in our estimates." Finally, a NOAA P-3 overflight flight "showed us there was oil stretched out for several hundred miles. It told us they weren't containing much of it, and that it would float a long way. We believed that if it would float 300 miles to Tampico it would float a couple of hundred more to Texas. From that point, we began to rely heavily on the Galt model." And on people . . . .

As the weeks pass, Robinson's scientific party grows. Robinson dips deeply into NOAA—for the *Buffalo* and its crew, weather forecasters, fisheries biologists and chemists. the Huey 'copter from the Research Facilities Center in Miami, and even the ocean chemistry cruise of the *Researcher*. Virtually every office that could help was tapped.

"I was happy to see NOAA step in the way it did," Robinson says. "We had a remaining budget of about $200,000 and we had to spend more than a million. We ultimately used 50 or 60 NOAA people to do the job. It was really a large commitment from the agency."

At the same time, his hazardous materials group is threatened with sharp curtailments in personnel. The cut touches a problem of philosophy: can NOAA support 14 people who, like a fire department, are preparing for some future event? Or should untrained people be taken "out of hide," in Madson's terms, when an emergency arises? Robinson favors the fire department approach. For a while during the Campeche spill, he says, "We were afraid we'd get another one while we were stretched too thin in Corpus Christi. Just about every trained NOAA person was already detailed to the Ixtoc spill."

There are also more than a hundred specialists attending Ixtoc from other U.S. agencies and from the State of Texas. Every few days the group grows by 10 to 15 people. There are management problems. Everything must be rethought every day, starting at a 6 p.m. freeform meeting. Scientific strategies are run off, shaped, handled, always with an eye for some new way to get the job done sooner. Should an amphibian be rented to go out and sample the oil? May we should . . .

Robinson takes it all in, drawing seemingly limitless energy from his omnipresent soda pop. Later he reports the news to the Coast Guard OSC. Sometimes his news is good, sometimes awful.

Robinson, barely 40 with the aura of an early achiever, attracts the media as sugar draws bees. The daily briefings focus on scientific work, and so on him. A news office running 14 hours a day cannot dent media interest in the spill or in the man running the scientific part of the response. At dawn one day he gives a live interview to national television in a mosquito-besieged meadow north of Corpus Christi. He ungrudgingly spends 30 percent of his time providing information to the media: "It is extremely important that everybody understand what we're doing and why. We need the public's support. . . . For example, if we decide to leave a stretch of oiled beach to heal naturally, we want people to know our reasons for doing it," he explains. "Public confidence is everything."

He sees the oil's impact as large but incalculable without further

Photo: Coast Guard

On-Scene Coordinator, Capt. Roger Madson, USCG (in coveralls) briefs inspection team of (left to right) NOAA Administrator Richard A. Frank, Coast Guard Commandant Adm. John B. Hayes, and NOAA Assistant Administrator for Fisheries Terry Leitzell.

study. "We estimate that some 3 million gallons of oil came ashore in Texas. I don't feel the impact was light. . . . But we have to look into it. . . ."

His interest toward the end of the year thus swings to getting money for a long-term effects study, "a 3-year, $9 million assessment program . . . It's the first opportunity we've had on this scale to do a thorough study." All the elements are present to make it worthwhile: two years of baseline data from the Bureau of Land Management, advice from some 1,200 scientists around the country on the best means of doing the assessment, and scientists on the scene since a month before the oil came ashore. "It isn't likely to happen again that all these elements are satisfied," says Robinson.

Clean-up teams collect tarballs and oiled sand from Padre Island beach for trucking back to State- and EPA-approved disposal site.

Photo: Coast Guard

For a time earlier in the year, the oil seems an irresistible and elusive force. But at an evening meeting in early September, Robinson learns the currents have begun setting to the south, 3 to 4 weeks ahead of the most optimistic estimates.

Robinson relays the word, a good word that means the oil will not stain the vulnerable Louisiana coast unless the well remains uncapped at the next seasonal current reversal, in February.

Carole O'Toole

"Chain of custody" sounds like the title of a murder mystery. In fact, it refers to the list of hands through which a scientific sample passes from its sealing in a container to analysis in a laboratory. Without this chain, a sample has no legal validity and little value in assessing the impact of Ixtoc-1 oil along the Texas shores. Data manager of the Corpus Christi response team, Carole O'Toole is keeper of the thousands of samples in jars and plastic bags.

She has been in Corpus Christi since early August, from the days when most of the NOAA team lived in a beachfront motel.

Her policy is crisp and simple. "No one leaves this room without giving me a daily summary," she announces at her first evening meeting. The system works.

She spends her time putting order into a mountain of data. "We've got four freezers overflowing with samples," she says, samples brought back by the *Researcher*, by the EPA ship *Antelope*, and by all the others. The samples are a bit of everything, most of them slated for chemical analysis to determine what is Ixtoc-I oil and what is not. She also cross-references biological samples taken before the oil came in so that investigators can trace then through the computer.

For O'Toole, the worst thing is not the killing schedule, the mounting pile of samples, personal dislocations, or even the blistering Corpus summer. It is the oil itself.

"We'd go down to the beach and watch it come in," she says. "It was just horrible, seeing it move up

Photo: Coast Guard

Volunteers at Fish and Wildlife Service bird-cleaning station try to rescue blue booby that was entrapped in the oil.

on the beaches. . . . You wonder whether the next storm will bring it in. It's like a horror movie where you're not sure the monster really dies at the end."

Corpus Christi is a city easily seen, and if it isn't your town, 4 months can be a long time. "It's been very hard on families," says O'Toole. "The work demands all of your time and dedication. It's like being in a fishbowl. You're with the same people 24 hours a day. You can't escape your job . . . Sometimes you just want to meet someone who doesn't know what an oilspill is." She laughs.

Bob Pavia

As the mild Gulf winter settles upon the shining rim of beach that ties Corpus Christi to the sea, the NOAA hazardous materials folk begin to think ahead to other spills. Winter is the season of heavy weather at sea, the season of spills. Christmas is a magnet for catastrophes. NOAA oceanographer Bob Pavia is one of the scientific party waiting for that next spill, that next maximum effort.

Pavia has been with the Campeche response since early July. Spills have pretty much dominated his short career with NOAA, where he arrived as an intern fulfilling part of his master's requirement in 1978, worked the Puerto Rico spill, returned to Oregon State for his degree, and rejoined the agency in time for the Ixtoc-I disaster. At 25, he shoulders large issues, speaks for the scientific team, does the necessary and sometimes runs into conflict with people of broader experience.

Much of Pavia's summer is spent on the NOAA *Buffalo*, mapping the stringy brown mess drifting north, the infinity of sheen. It is a mixed bag, all that flying. "In a way, it was an emotional low, I kind of burned out," he says. "But looking back, the aerial part was valuable experience for me. Now I want to do a manual on aerial observations of oil spills that inexperienced people can use."

He describes his Ixtoc tour in terms of "phases" of the response: the first days at San Antonio "close to the edge of everything"; the *Valiant* cruise, "an entirely new experience . . . more like real oceanography for me. . . .

When we got back after only five days on the ship everything had grown so much. . . ."

The last phase for Pavia is damage assessment, the leading edge of the long-term study Robinson hopes to get going. "I'm helping with the technical development plan and our summary report," says Pavia. "Also planning some field operations. Mainly, we want to plug some gaps in our knowledge of where the oil is offshore. . . . We assume the oil on the beaches removed by the September storms has to be somewhere, probably offshore."

In this phase, Pavia will be taking samples from just offshore to the continental shelf. "Right now," he says, "we don't have much evidence of heavy impact, but some effects can be quite subtle. For instance, we didn't get many oiled birds from this because the birds moved to unoiled areas. But we don't know what impact there is on the birds already in those areas when displaced strangers come in."

Pavia rotates his assignment now, traveling every two weeks from Corpus to his office in Bay St. Louis, Miss. It is dislocating, for the tempos of office and field work are quite different. "You spend 30 percent of your life readjusting to where you are."

Bob Pavia and other NOAA people continue their displaced lives, beginning to measure environmental damage from IXTOC-1 oil. There is little contact now between NOAA team and Coast Guard. Booms and barriers are coming out of the water to be cleaned for use on the next spill. IXTOC-1 wears its metal sombrero. The massive Federal response seems over.

But along the far side of the Gulf, Coast Guard C-130's still scout the waters north of Ixtoc-1 for new currents moving oil toward Florida.

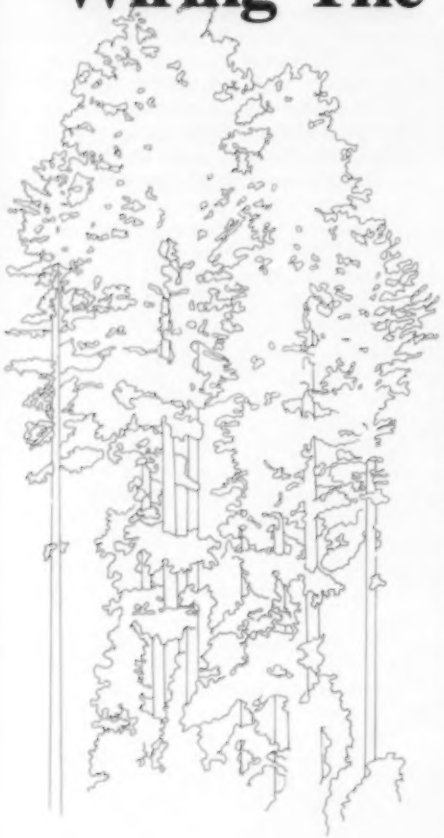
Did the monster really die?

Cartoon: Carl Posey

Energy Processes in a Forest

By JOAN FRISCH

Wiring The Woods For Weather



Far in a western brookland
That bred me long ago
The poplars stand and tremble
By pools I used to know.

—Alfred Edward Housman
From *"A Shropshire Lad"*

Spread across the northern hemisphere, the pervasive poplars stand and tremble, sharing their beauty, shade, and wood with us. Now, a group of them in Tennessee is also beginning to share the secrets of the small, internal weather that links the leaves of these trees with meteorological processes at much larger scales.

Because forests cover about one-third of the Earth's land surface, they affect large weather patterns. Through photosynthesis they take in carbon dioxide and give out oxygen, and thus are crucial in controlling carbon dioxide levels in the atmosphere.

They also modify the humidity of a region by transpiring great quantities of water vapor into the air.

But in addition, each particular woodland contains its own microweather—weather controlled by the geometric arrangement of the leafy canopies, the sun's elevation, the amount of moisture in the air, the season of the year, and the intricacies of leaf size and shape.

"We know that forests have a substantial influence on our atmosphere, but we really don't know how their internal weather functions," explains Dr. Boyd Hutchison, a forest meteorologist who works at the Atmospheric Turbulence and Diffusion Laboratory, a NOAA facility in Oak Ridge, Tenn. "Until we do, we really can't understand what's happening to solar radiation in a forest or in the lower atmosphere—how it interacts with carbon dioxide and water as part of the tree's energy-making processes."

The overall reason for Hutchinson's research is to gather information for modeling photosynthesis among different kinds of trees, leading to a better understanding of forest productivity—the growth of trees and plants. This productivity, says Hutchison, depends upon the arrangement of the tree's leaf canopy or "umbrella" and the sun's radiation, soil moisture, fertility, other climatological variables.

If forests were uniform in height and density, like a plush green carpet, meteorologists trying to model their interaction with the atmosphere would have a relatively easy task. Instead, woodlands are complex and three-dimensional, consisting of tall trees such as tuliptrees mixed with shorter, bushier trees—mountain laurel and flowering dogwood, for example. How they respond to the atmosphere depends on how much sunlight and carbon dioxide reach different levels in the trees' leafy structure.

The atmosphere's characteristics—radiation and energy balances, temperature, water vapor, carbon dioxide and wind speed—can be estimated relatively simply, but the forests' interactions with them are much more difficult to determine.

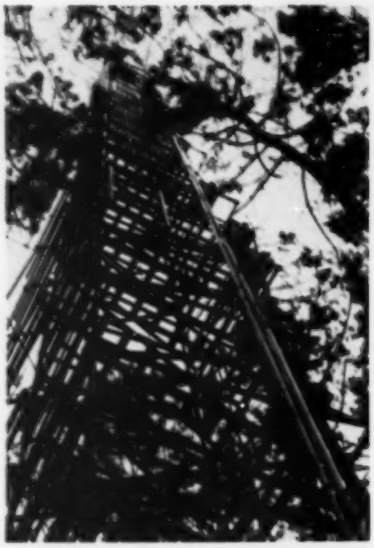
For example, photosynthesis and respiration processes taking place within the leafy foliage of a forest respond to the physical state of the atmosphere—how much sunlight is present, how much carbon dioxide is in the air surrounding the forest. These conditions can vary from hour to hour, day to day, season to season.

To bridge the gap between what meteorologists know about continental and global weather patterns

and what they don't know about the small-scale meteorology of forests, Hutchison and his physicist colleague, Dr. Detlef R. Matt, have instrumented two types of eastern forest—the climax oak-hickory and the younger tuliptree. By "wiring" the forests with devices that measure solar radiation, the two Oak Ridge scientists will attempt to determine how a single treetop leaf layer of an oak-hickory woods and the multiple leaf layers of a tuliptree forest affect small-scale weather and energy processes within them.

The pair want to know how the leaf arrangement and total leaf structure of a forest type affect its photosynthetic production—the rate at which it uses carbon dioxide and water, with the aid of sunlight, to produce carbon and hydrogen (as stored energy) and oxygen (as waste). When the sun's piercing rays strike the chlorophyll in a leaf, the chemical stores the energy within its molecular bonds. Later, when the chlorophyll is exposed to carbon dioxide and water molecules, they combine with the energy stored in the chlorphyll to produce sugar for the tree's energy needs. Excess oxygen, a byproduct of the reaction, escapes into the atmosphere.

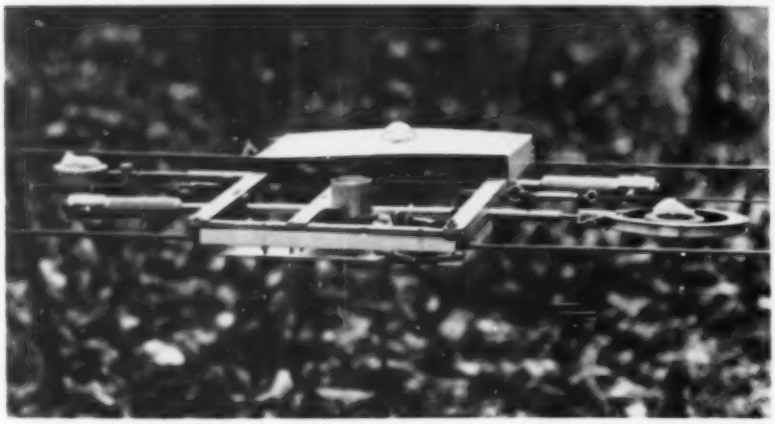
This energy-plus-oxygen-making cycle has been the centerpiece for a meteorological study within the Oak Ridge area of a deciduous (nonevergreen) forest dominated by tuliptrees. The aim is to determine the variation of solar radiation received



by the forest during different seasons of the year.

Results of the tuliptree forest research showed that the greatest amounts of sunlight or solar radiation did not reach the trees during the summer when the sun shone the longest, but instead, when the sun penetrated the forest during early spring before the trees began to leaf out.

Instrumented "tram" system that moves through the forest on cables hung from towers (photo above), with upward- and downward-facing sensors that constantly measure three kinds of radiation.



After the trees leaf out in the spring, the proportion of sunlight received by any leaf depends upon the amount of cloudiness, the solar elevation, and the structural characteristics of the tree's canopy—its leaf angles and leaf surface areas.

"Since light is a limiting factor for plant survival on the forest floor, plants have evolved at least two adaptations to this light-limited environment," Hutchison explains. "First is varying shade tolerance. Some plants can produce a given amount of stored energy in dimmer light than others. They apparently use what light they do receive more efficiently, and we call them 'shade tolerant'—such trees as dogwood, sassafras, hazel, and sourwood."

The second form of adaptation to light limitations is short periods of growth. It is seen in the rapid springtime development of some wild flowers, like the mayapples or Dutchmans breeches.

"They sprout when maximum sunshine is available because the trees have yet to grow their new leaves," Hutchison says. "They grow, flower, and produce seed as the trees above them leaf out."

By the time the forest is fully leafed, they have completed their annual growth and reproductive cycle and quickly die back and disappear.

To get a closer look at this form of adaptation, the NOAA scientists are trying to find out how gaps in the tree's leaf canopy distribute light and stored energy to the forest below.

This process, Hutchison says, is affected by the kind of day. For example, on a clear day 80 percent of the sunlight may arrive at the forest as direct beam radiation, while the other 20 percent is present as diffuse radiation—radiation scattered by particles in the sky. Haze, pollution, and dust increase this scattering of sunlight. On a cloudy day, all the sunlight is diffused by clouds covering the sky, and the light rays (solar radiation) arrive from all directions.

The outermost leaves in the tops of the stately tuliptrees, ashs and

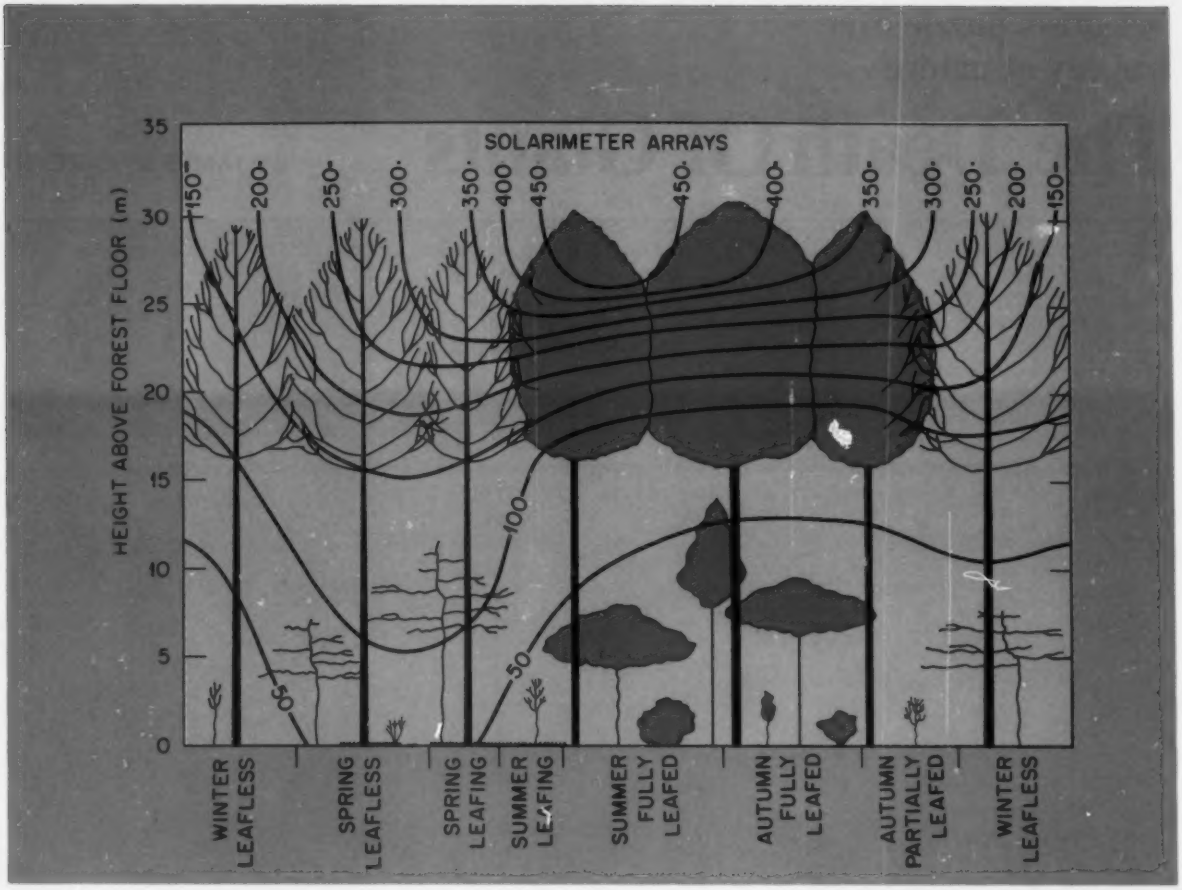


Chart of the seven "seasons" of a southern Appalachians broad-leaved forest, showing the amount of solar radiation received at different levels during each season.

hickories are highly productive because they literally are "bathed in sunshine" due to their proximity to the sun's rays. However, photosynthesis in these leaves may be limited because, like an eager sunbather, they get too much solar radiation—so much that it destroys chlorophyll faster than the leaves can synthesize it. Consequently, leaves in the upper portions of a tree tend to grow more nearly vertical than horizontal, thus reducing the radiant energy that they absorb and increasing the reflection of solar energy downward into the forest where leaves receive too little radiation rather than too much.

Just as the topmost leaves receive more radiation, the forest absorbs more energy when the sun is high in the sky.

At present, deciduous, broad-leaved forests such as the oak-hickory stands in the eastern part of the United States are part of a middle latitude forest belt that, in a woodsman's terms, is considered the richest in North America. The chief reasons for this abundance of oaks and hickories are the cyclic periods of continental glaciation and the present climate, which is intermediate between northerly and tropical. After northern tree species "migrated" far southward ahead of the glaciers, some of the trees remained as the glaciers retreated, particularly at higher, cooler altitudes in the Appalachians, the Smokies, the Catskills, and the Alleghenies, while southern species such as the beeches, magnolias, and sweetgum returned.

Until Hutchison and Matt initiated this research project, no other studies had been published concerning the distribution in space or time of solar radiation within the forest canopy.

High quality measurements of solar radiation in the fragrant forests of Tennessee will provide the scientists with valuable data for use in related numerical models of wind flow and temperature field, and other components of forest meteorology. In this way, Hutchison and Matt hope to clarify the role of deciduous trees in the complex equations of weather and climate.

Scientists puzzle over tragedy of nature

The Death Of Giants

BY JAMES R. LARISON

As the tide ran out on the evening of June 16, 1979, 41 giant sperm whales began to die on a sand beach in Oregon. They blew frothy blood from their blow holes and aspirated sand. The beach shook when a 20-ton bull struck it with his tail. From somewhere inside the body of a sleek, slate-gray whale came a clicking sound—probably the remains of her echolocating system—a system which apparently failed to keep an entire family of whales from ploughing into the shore.

Bruce R. Mate, an assistant professor of oceanography and Sea Grant investigator at Oregon State University, was notified by the Oregon State Police. As coordinator of the Northwest Marine Mammal Stranding Alert Network, he was the right person to call. He spent most of that night on the telephone arranging for equipment and organizing a crew of marine mammal specialists.

Most of the scientific crew and our own Sea Grant communications staff arrived on the beach at first light. Our worst fears were immediately confirmed. The whales had come ashore at the highest point of the tide. There would be no higher tide for at least a week.

In those early hours, before dawn, you could see a half mile of black bodies lying in waist-deep water, their flukes waving in the air. The whales were on their sides and were partially covered with sand.

By sunrise the beach was crowded with people, tripods, and film crews. One man carried his young daughter out into the breakers, placed her on top of a dying whale, and stepped back for a photograph.

James R. Larison is a Sea Grant communicator at Oregon State University.

Airplanes seemed to come from every direction. They were stacked up in a counter-clockwise holding pattern, each waiting its turn to pass over the whales. Electric drive and auto-wind cameras clicked away.

A Coast Guard helicopter came to help—perhaps to tow a whale back to sea. But the whales were too heavy to be moved. The smallest weighed ten tons, and a few of the larger bulls weighed more than twice that. Pulling them back to sea would have required some very specialized equipment, and a lot of time, neither of which was available.

It was painfully obvious to most of us that the whales were not going to leave that beach. They would die right there where they'd come ashore.

But if the whales could not be saved, at least we could see that they did not die in vain. The scientific teams began working immediately. They divided into crews and began working from north to south, measuring, marking, and photographing each whale.

LaVern Weber, director of the Oregon State Marine Science Center, doctors, and Tag Gornall of Hubb's Sea World, took blood samples from the tails of each of the live whales, and rushed them to the laboratory.

The first few days were frustrating for the scientific crews. They didn't know how to deal with the suffering. Some of the whales died immediately, but others hung on for days. Nothing could be done to save them.

Euthanasia was on the minds of everyone in the scientific team from the moment it became apparent the whales were going to die. But how do you dispatch a twenty or thirty-ton whale? Once you've decided to do it, how do you explain your decision to the five thousand people watching you?

Photo: Oregon State University

The decision to try was made jointly by the five veterinarians on the beach. They put their heads together and decided to use a fast-acting and powerful drug, M-99. But even M-99 didn't work; it put the whales into a physiological condition much like the condition they go into when deep-diving. They stopped breathing and their hearts slowed down, but they weren't dead. The scientists and veterinarians were emotionally involved by this time. It was painful for all of us to watch.

Ultimately, it was the sun, the dry air, and the internal organ damage that killed most of the whales.

During the first two days, Mate and the team of scientists worked long hours. They did necropsies quickly in a struggle against time and deteriorating tissues. Blood, liver, kidney, heart, lung, stomach, muscle, fat, and eye samples were taken from the animals. Three near-term fetuses were found; each weighed nearly a ton.

All 1600 teeth and two full skeletons were saved. Worth $200 each, the teeth became a security problem. The State Police secured the beach day and night. Despite their efforts, one man crawled across the beach at night and pried several teeth loose before he was caught and charged.

By the end of the second day, the sun had done its work. Bloating became a problem and there was the constant danger of explosion. The air was heavy with the stench. People began to plan disposal techniques. But how do you dispose of 600 tons of whale? You can't move them without substantial cost and public health risk. If you bury them on the beach, Oregon's winter storms would most likely expose the remains and scatter carcasses up and down the beach for miles.

After many long beach-side conferences, the various local, state, and federal agencies decided to use a napalm-like substance and to burn the carcasses.

The process worked well; there was very little smoke. The carcasses were reduced to ash and the remains were buried.

A week after the sperm whales came ashore, it was all over in Florence. Normal beach activity resumed. But the scientists will be busy in their laboratories for months. Dental aging and an assessment of reproductive history will be done by the National Marine Fisheries Service in Seattle. Corneas are being cultured in a genetics study at the University of Oregon. Eye lenses are being used to age the whales. Histo-pathology, bacteriology, and parasitology work is being done at California State. Others are looking for chlorinated hydrocarbons. Bruce Mate is analyzing stomach contents.

The journals will be publishing these results for years.

Many of the questions we all had on the first day still cannot be answered. We know that some of the animals were sick. Their white blood cells were abnormal. But others were not. It is possible that sickness caused the first (perhaps the lead) whale to strand, but the others almost certainly came ashore in response to some sort of social phenomenon. They may have simply followed the leader.

Giant sperm whales have always been a mystery to us. They usually stay far out to sea, diving and feeding half a mile below the surface. Until this stranding, most of our scientific data came from harpooned bulls. The accumulated data from Florence may prove to be the biggest single source of scientific information on sperm whales that exists. We may know more about this family unit, and more about single whales, in life and in death, than is known about any sperm whale in history—with the possible exception of Moby Dick, of course.

Photo: Oregon State University

Dr. Bruce Mate, Assistant Professor of Oceanography at Oregon State University, examines a tooth from one of the whales.

Sperm Whales

The giant sperm whale has a head that comprises one-third of its total body length. Its lower jaw flaunts two rows of six to seven-inch teeth. Sucker marks, and shark and killer whale scars mar the otherwise smooth, sleek skin.

Largest of the toothed whales, some bull sperms reach 58 feet and as many tons. The female is smaller, perhaps 38 feet. An S-shaped blow hole is located at the left side of the front of the head.

Sperm whales roam all the oceans of the world, but are concentrated in temperate waters.

Sperms are well-known for their deep dives. The remains of one sperm whale was found entangled in a submarine cable at 3,720 feet. Others have been tracked by sonar to depths of a mile and a half.

They apparently dive in search of squid, their preferred food. Less often they eat other fish; sharks, rockfish, hake, even an occasional salmon.

There is no light in the feeding grounds of the sperm whale. They apparently use a sophisticated sonar system for finding their way, and locating their food. Sperms make complicated clicking sounds as they swim. Each whale has a different pattern of clicks—a signature all his own. The signature could be helpful to the sperm whale in decoding and distinguishing between reflected sound pulses. The U.S. Navy has emulated the clicking pattern for its own sonars.

We know little about reproductive history and longevity of sperm whales. How many young does a typical female bear? How often? We know that females often congregate and remain together for part of the year at least. These nurseries may vary in size from a dozen to several hundred whales.

Some researchers believe that calves are born to females after a gestation period of slightly more than one year. They remain alongside the female for as much as two years, nursing and slowly learning to feed. A female may give birth to one calf every four years.

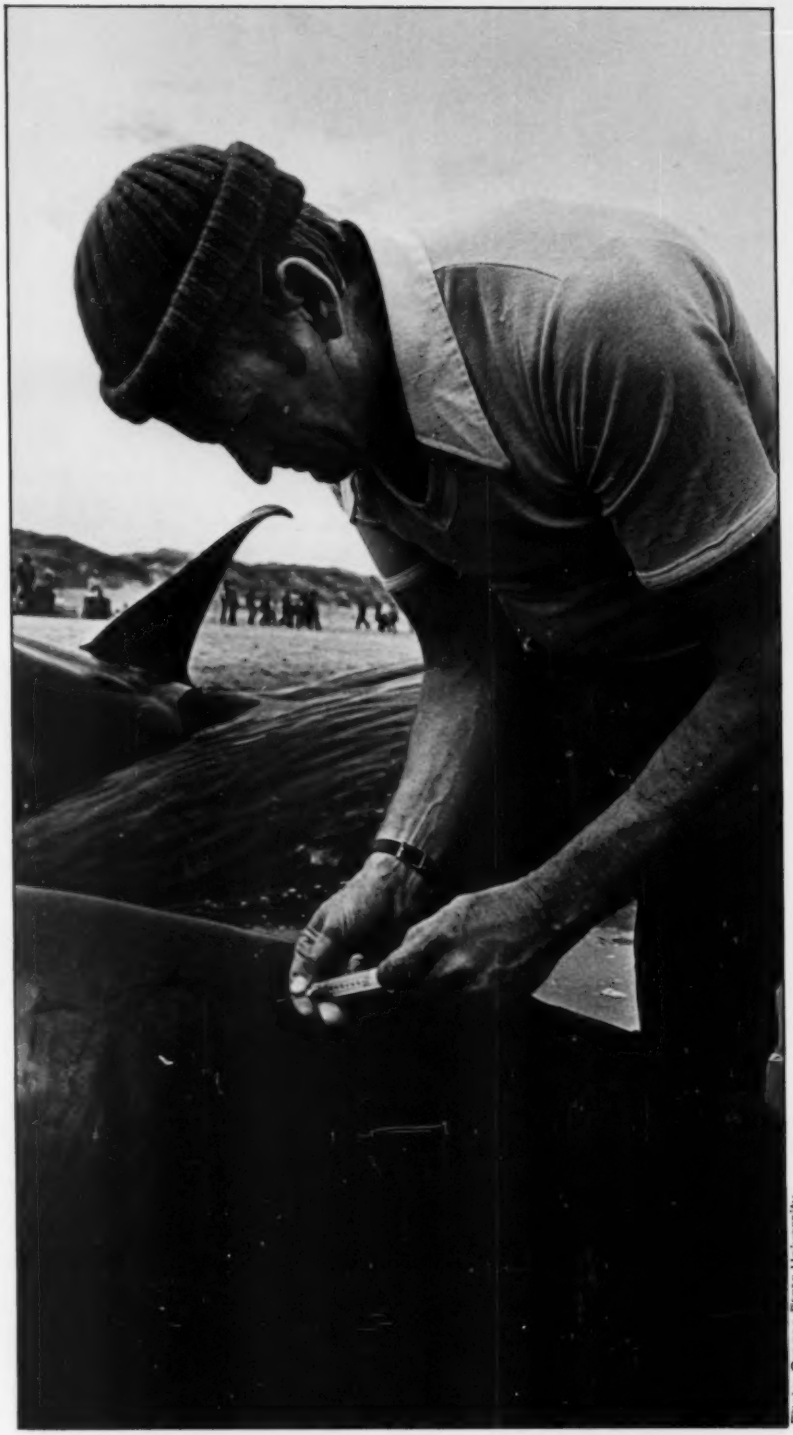


Photo: Oregon State University

Lavern Weber, Director of the Oregon State University Marine Science Center, injects a fast-acting drug into one of the animals.

Part I

MURT divers check it out

By LT. (J.G.) CHARLES GROSS

"Ground Truth," With Bubbles

The research vessel slows to a stop 80 feet above the bottom of Stellwegen Bank, 10 miles north of Cape Cod.

Two divers in gear slip over the side and swim to the bottom.

It promises to be a good day for research: bottom sandy, seas at 2 to 3 feet, bottom visibility 20 feet, and water not too cold. Best of all, the area is rich in scallops.

The divers and their ship—the 60 – foot gear research vessel *Rorqual*—are from a NOAA laboratory in Woods Hole, Mass. Today they will compare the actions and "fishing ability" of a commercial scallop dredge and a dredge used by scientists.

The *Rorqual* crew drops the test dredge over the side, and it settles on the bottom. A diver grabs a TV camera and follows the dredge. He will shoot color film; the other diver will tend camera cables and watch diver and dredge.

The *Rorqual* crosses the bed at about one knot. The diver swings the camera into position and monitors the tow and the effects of the dredge on the bottom.

The vessel stops, divers ascend, and the dredge is hauled to the surface. By sunset, the experiment will be done twice with each of the test dredges. Engineers will use the information obtained to evaluate survey methods and to change dredge design to increase efficiency while reducing harm to sea life.

The task is one of many performed by the eight members of the Manned Undersea Research and Technology (MURT) team stationed at the Northeast Fisheries Center in Woods Hole, Mass.

The MURT, headed by Dr. Richard Cooper, was established in 1973 to use diving and its associated technologies in conduct marine research. "All team members are experienced divers and have participated in a wide range of scientific diving programs," said Cooper. "We have more than 75 years of diving experience in the team."

As in any diving operation, safety is a primary consideration. Two of the group, Cliff Newell and Roger Clifford, are certified Emergency Medical Technicians versed in recompression techniques. Other members of the team, Ken Pecci, Joe Uzmann, Kevin McCarthy, Tom Meyrs, and I, are fishery biologists.

. . . to extend research diving to the edge of the Continental Shelf and beyond. . .

Scientists using fishing and sampling gear, such as the scallop dredges, must know exactly how each one works and whether it is performing as it should. This "ground truth" can best be obtained by divers or people in submersibles actually watching what happens. Ground truth teams also check the accuracy of mechanical samplings against what they see about them on the ocean floor.

"We've made more than 100 dives in little research submersibles to study the ecology and geology of 14 under-water canyons along the New England and Mid-Atlantic Continental Shelf," said Cooper. "The canyons are under increasing pressure for fisheries and oil and gas development, and it is important to establish baseline data before additional development occurs."

Environmental monitoring of the coastal waters' plants and animals is another important aspect of Cooper's research. His group, assisted by diver scientists from Southeastern Massachusett University and the University of New Hampshire, has established four monitoring sites on the New England Continental Shelf.

"Each location was chosen for a specific reason," said Cooper:

- Cashes Ledge and Jeffreys Ledge in the Gulf of Maine, for their pristine condition and position in the prime offshore fishing banks.
- a deep water site at Oceanographer Canyon, a projected oil and gas drilling location.
- a site off the New York coast already marked by commercial development.

According to Cooper, several indicator species of plants and animals have been chosen because they are known to accumulate certain pollutants including oil, chemicals, and nuclear wastes. They will act as a biological early warning systems of human-induced changes that could cause catastrophic damage to the ecosystem.

The use of divers is important here to collect intact and unstressed animal and plant samples; otherwise the data could be contaminated or biased. Samples are best collected from the same site to avoid geographic variation.

Study methods used at Ocean Pulse sites include analysis of high resolution closeup photographs of plants and animals. Photographic study minimizes disturbances by diver scientists.

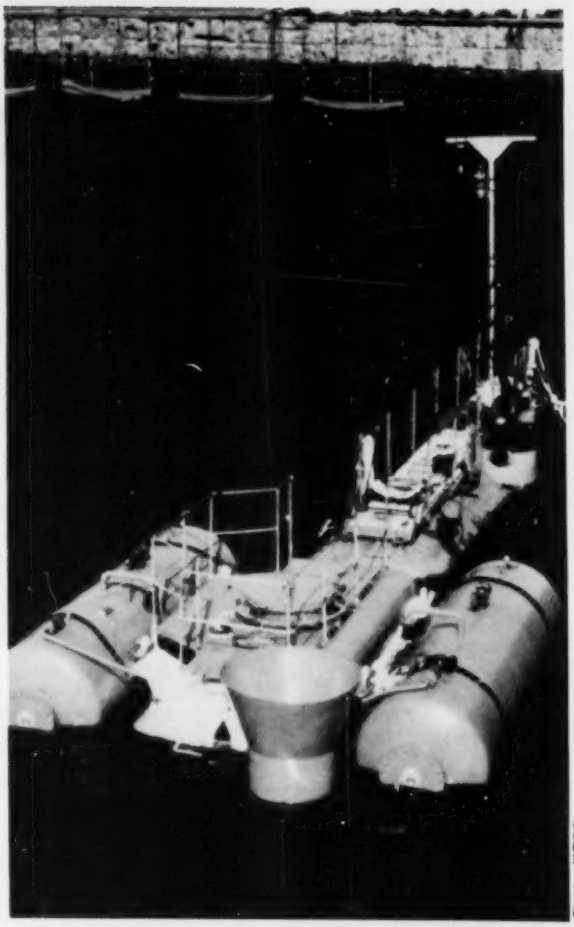
"We hope to extend research diving capabilities to the edge of the Continental Shelf and beyond," Cooper said. "There is a continual evolution of diving technology and the group is constantly evaluating new techniques."

That, however, is another story. ●

Lt. Gross, a NOAA Corps officer, is a member of the diving unit at the Northeast Fisheries Center

Photo: NOAA

Photo: NOAA



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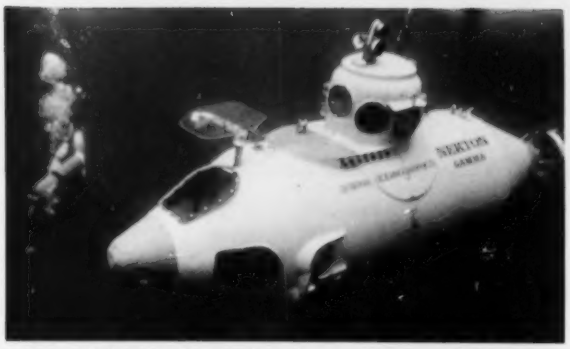

Divers (left) check out what they see deep under water with what they have deduced from the readings of instruments and the samples from bottom grabs. German habitat Helgoland (top), a major facility used by MURT divers studying herring, rests on surface at Woods Hole before being towed to submersion site; below, submersible and diver go down for another look.

By BRIAN GORMAN

U.S.S. MONITOR, The First . . .

The U.S.S. *Monitor* was a queen among ships. She was the first ship built entirely of iron, the first ship with a revolving gun turret, the first ship with marine toilets below the waterline, the first ship with an anchor that could be raised and lowered from below deck, the first ship with forced-air ventilation, and last, but not least, the first ship to become a U.S. marine sanctuary.

The list seems endless. Yet none of those unique features can account for the fascination, the romance, and the charisma that have enveloped this bizarre, flat-decked battleship from the day of her launching at New York, January 30, 1862.

To her contemporaries, she must have resembled a Civil War battleship as much as a DC-10 looks like the Wright brothers' first flying machine. In an age when huge, steam-powered side wheels propelled wooden vessels carrying eighteenth-century spars, rigging, and sail, the *Monitor* was as stark as a modern submarine. In full battle dress, she carried not an inch of cordage. Her iron-plated deck was as flat as an aircraft carrier's. Her 18 inches of freeboard let her sit so low in the water that she was a nearly impossible target for Confederate guns. In dramatic contrast, the naked, wood-hulled men-of-war of the period rose vulnerably 15, 18, 20 feet above water, topped by masts sometimes another 180 feet high.

Smack in the middle of her 172-foot deck stood her 200-ton turret: 9 feet high, 21 feet across, able to revolve 360 degrees in less than a minute. And from within the turret's 8-inch-thick layers of the best armor Union money could buy, glowered two enormous 11-inch Dahlgren cannons.

No wonder official Navy observers at her launching didn't know whether to laugh or cry. As events turned out, they needn't have done either. The *Monitor* was towed to Hampton Roads, Va., in March 1862, after her sea trials. On the way, she engaged the C.S.S. *Virginia*, formerly the wooden U.S.S. *Merrimac*, captured from Union forces earlier in the war and fitted with iron plates by the South. Neither side wanted a real confrontation, and both retired from the 4-hour engagement scarred but undamaged. The battle was, according to the history books, a standoff.

Tactically, however, the "battle of the ironclads" was not a standoff. The *Virginia* had all but broken the Union's blockade at Hampton Roads, devastating the North's fleet, sinking or crippling a number of ships earlier that day. Although the *Monitor* did no real damage to the *Virginia*, the encounter squelched the Confederacy's nearly successful attempt to break the blockade.

More than that, the *Monitor*'s first (and only) fight sounded the death knell for wooden ships. By the Civil War's end, the Union had built more than 36 Monitor-class battleships, some with two turrets. Never again did a modern navy build wooden warships. Iron, steel, and revolving gun turrets became the hallmarks of fighting ships everywhere.

Her role in history over, the *Monitor* spent the rest of 1862 on blockade duty at Hampton Roads. On Christmas Eve, she was ordered south to North Carolina for recovery operations against Fort Fisher. A week later, on New Year's Eve, while under tow by the U.S.S. *Rhode Island*, she sank in a raging storm off Cape Hatteras, N.C., taking with her 4 officers and 12 crewmen.

She took with her, as well, for 111 years, the secret of her resting

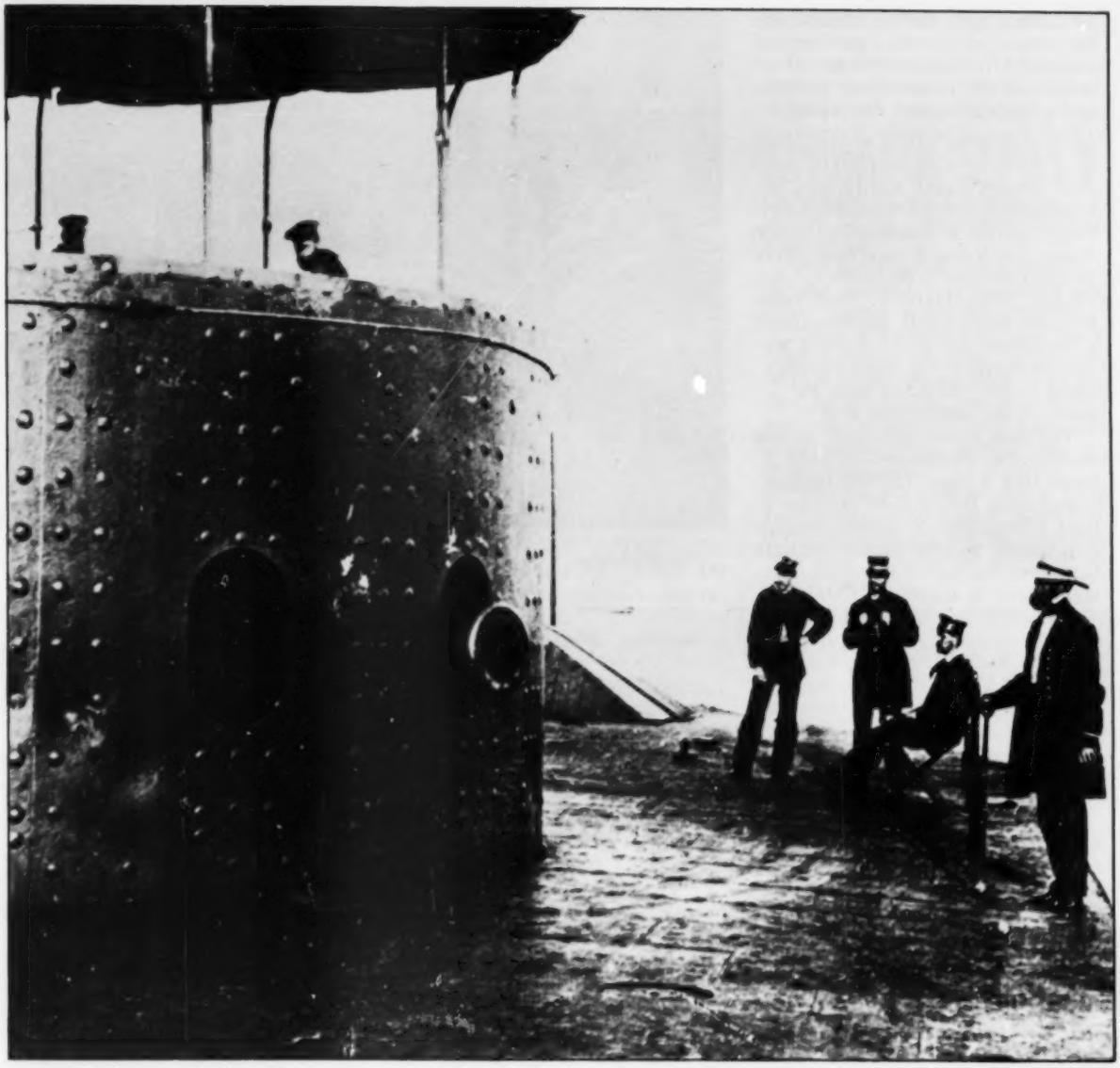

Photo: U.S. Navy

Officers of U.S.S. MONITOR examine the revolving turret, one of the many revolutionary features of the historic ship. Dents caused by cannonballs are partly visible.

place. Not until 1973 did a Duke University expedition locate her remains, 16 miles off Hatteras in 220 feet of water. In September 1974, the Governor of North Carolina nominated the wreck to be the Nation's first marine sanctuary, as part of the National Oceanic and Atmospheric Administration's newly granted Congressional authority. The official designation was made January 30, 1975.

Since that time, a number of scientific expeditions have explored the wreck. She rests upside down, supported partially by her famous turret, dislodged and lying near her stern.

Most expeditions had been confined mainly to photoreconnaissance or television observation, but in 1977, a diving team from NOAA, the Florida-based research firm Harbor Branch Foundation, and the State of North Carolina's Division of Archives and History dove on the wreck, using one of Harbor Branch's four-man submersibles. During that joint mission, divers recovered the *Monitor*'s now famous red-lensed signal lantern and a 62-pound chunk of iron hull-plating.

Information from these early expeditions led NOAA, again col-

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laborating with Harbor Branch and the State of North Carolina, to undertake in August 1979 one of the most ambitious submarine archaeological expeditions of the century.

Using some of the world's most costly and sophisticated underwater hardware, including both Harbor Branch submersibles, marine archaeologists Gordon Watts and Richard Lawrence, from North Carolina's Division of Archives and History, and John Broadwater, their professional counterpart from Virginia's Research Center for Archaeology, made nearly 40 dives onto the remains of the once-proud ship.

The sub that took them to the wreck, the *Johnson-Sea-Link I*, looks like a lunar landing module. Dominated forward by a 4-inch-thick acrylic pilot's sphere, the sub is peppered with miniature thrusters that move the half-million-dollar vehicle about at depths of 1,000 feet. Twice each working day "Sub I" plopped into the Atlantic from the stern of its mother ship, the R/V *Johnson*. With her hydraulic launching crane aft, a divers' decompression chamber below, and networks of dials, switches, and gages, the *Johnson* could easily be confused with the set of *Star Wars*.

The expedition, August 1–26, had several goals. Perhaps the most exciting was recovery of artifacts from the captain's cabin. The *Monitor* had turned turtle as she sank. Much of her bottom plating had collapsed inward, corroded by 117 years under water and jarred by depth charges dropped when she was mistaken for a German submarine during World War II. As a result, divers could go directly into the cabin, avoiding the pitfalls of narrow passageways.

Twice a day, the archaeologists boarded Sub I. Slowly they descended through blue-green gloom to the wreck, led by the sub's sonar and, more often than not, by Sam, a 400-pound grouper, the *Monitor*'s self-appointed resident caretaker.

Once on the bottom, an archaeologist would slip into the 70-degree water from the cramped sub's pressurized dive chamber. Tethered to the sub by an umbilical cord containing a helium-oxygen breathing mixture and a voice communication cable, the diver would enter the wreck. Inside, a television camera monitored the sand and silt removal being done with a simple, vacuum cleaner-like dredge hose.

JOHNSON-SEA-LINK, research submersible of Harbor Branch Foundation, rests in its cradle on stern of mother ship prior to making another dive at the MONITOR site.

Progress was slow and unrewarding at first. More than four feet of sand, shell, silt, and clay had accumulated in the cabin. Each layer was different and archaeologically significant. On August 8 came the first discovery, an octagonal glass jar five inches high, embossed MUSTARD on one side, U.S. NAVY on the other. Two more mustard jars, a pepper bottle, and a sealed Mason jar full of pickle relish turned up. Members of the expedition wondered whether the *Monitor*'s crew had subsisted on hot dogs! "I was under a lot of pressure to come up with a ketchup bottle," quipped Watts.

What the archaeologists did find was far more exciting than ketchup bottles. The artifacts removed fulfilled the hopes of Kenneth Morris, a professional marine conservator borrowed from New York State's Division for Historic Preservation: several sections and a brass hinge from the mahogany cabinet over the Captain's sofa; a piece of leather bookbinding; a brass thimble used in making eye splices in rope, and a porcelain soap dish in mint condition. Outside the primary excavation site, other artifacts were discovered: a wine bottle; a "cathedral" bottle that may have held relish; a large fragment of a log-cabin-shaped bottle, probably commemorating Lincoln's inauguration, and an iron davit, one of a pair once mounted on the *Monitor*'s deck for launching her small boat. The prize was a strikingly beautiful brass lantern base, whose whale oil, long gone, had illuminated the officers' quarters, perhaps the Captain's own stateroom.

These items were taken for treatment to North Carolina's preservation facility at Kure Beach near Beaufort. Only swift action prevents the almost immediate deterioration of objects long immersed in salt water upon exposure to air. They should be fully stabilized in a year or two, to be put on public display, perhaps at the Smithsonian Institution in Washington, D.C.

The recovery of the artifacts, as exciting to both the divers and the public as it was, was not the only reason for the expedition. Lt. Cdr. Floyd Childress of the NOAA Corps, manager of the Monitor Marine Sanctuary, explains: "One thing we were most interested in was the condition of the ship. We knew from photographs taken during previous missions that there was substantial deterioration. . . . What we didn't know was how bad that damage might be."

At the back of everybody's mind was the question: Could the *Monitor* be raised? That question has haunted the ship and obsessed her fans ever since her discovery. The possibility of bringing up the Civil War relic in one piece holds an almost overwhelmingly allure for some *Monitor* buffs. Can it be done?

"It really doesn't seem possible," says Childress. "The evidence we saw last August—the entire hull forward of amidships utterly collapsed, gaping holes in the main deck, a nonexistent stern—[and] the opinion of a professional salvor who viewed the entire wreck . . . lead us to believe that there simply isn't any economically feasible method of raising the wreck that would also guarantee that the ship would not be damaged further in the process."

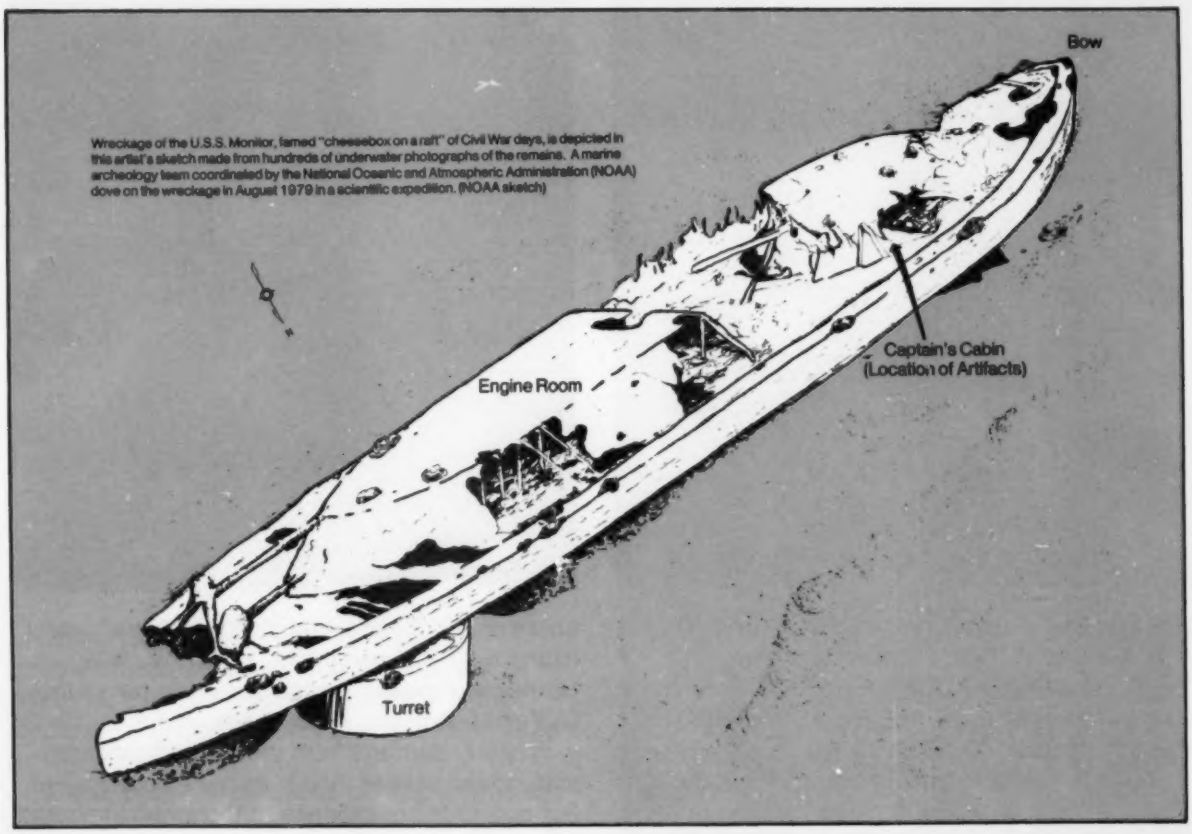
Even if the *Monitor* could be raised, adds Childress, "How on earth would it be preserved in such a way that the ship would have any meaning to the American public?"

A preliminary decision, based on early evidence, led NOAA Administrator Richard A. Frank to tell the press last August that NOAA "would not risk shattering the remains" of the *Monitor* in an attempt to raise her.

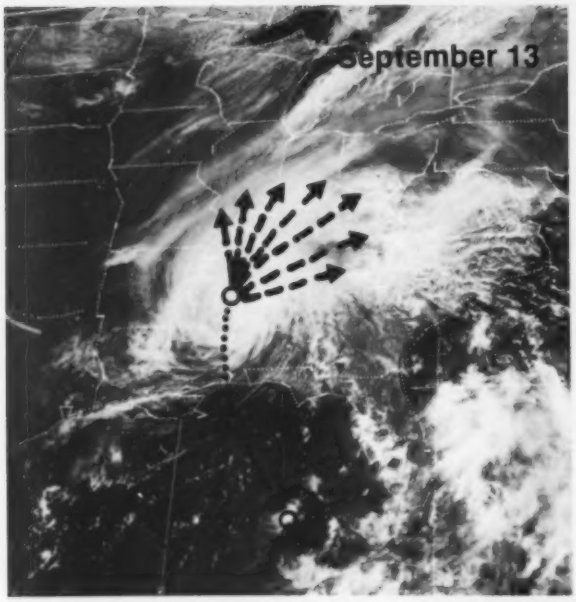
If the ship itself cannot be raised, parts of her, besides the artifacts removed last summer, may some day bask under museum lights. The *Monitor's* famous turret, her caloric steam engine, and other parts of her engineering equipment seem sturdy. In addition, the entire vessel is virtually a Civil War naval museum, containing all the everyday objects of the Union fleet's most modern warship.

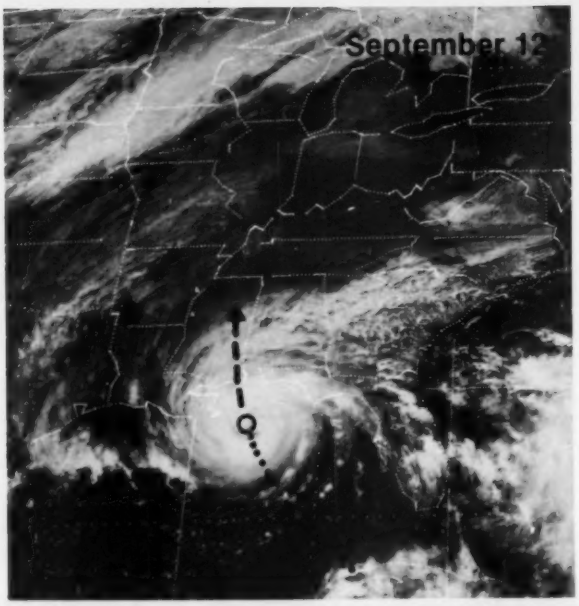
"No one has yet proposed studying the possibility of removing any more objects from the *Monitor*," explains Childress. Should such proposals be offered, however, NOAA would review them to ensure that the ship would not be damaged and that scientific and financial guarantees would protect any artifacts removed.

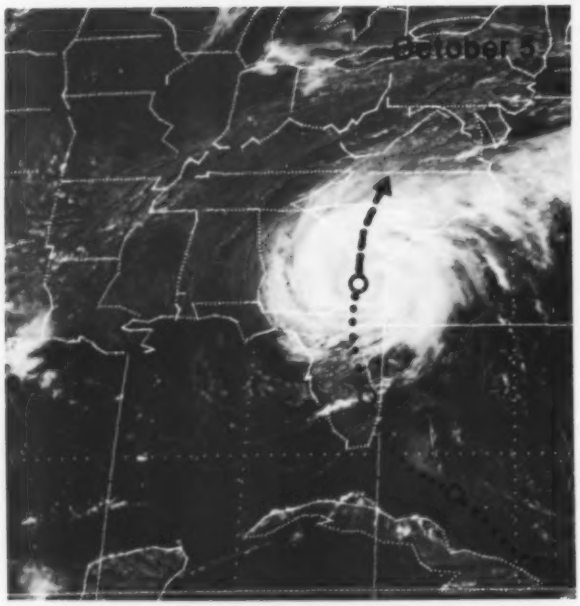
"We have a serious role to play here," says Childress. "NOAA is acting as a trustee for an irreplaceable piece of American history."

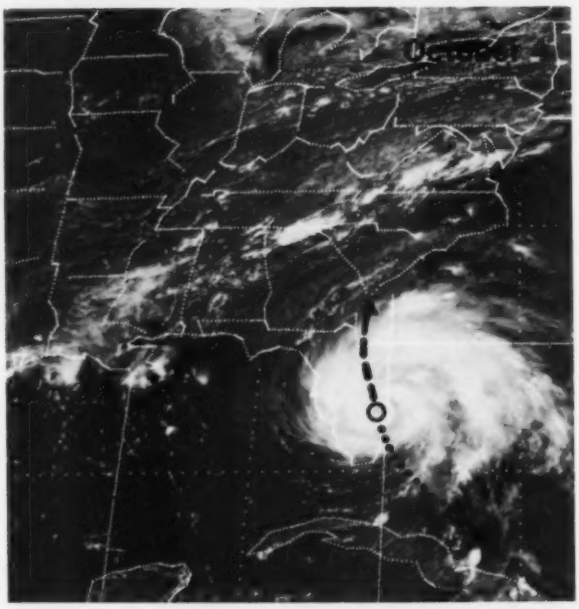


Wreckage of the U.S.S. Monitor, famed "cheesebox on a raft" of Civil War days, is depicted in this artist's sketch made from hundreds of underwater photographs of the remains. A marine archeology team coordinated by the National Oceanic and Atmospheric Administration (NOAA) dove on the wreckage in August 1979 in a scientific expedition. (NOAA sketch)



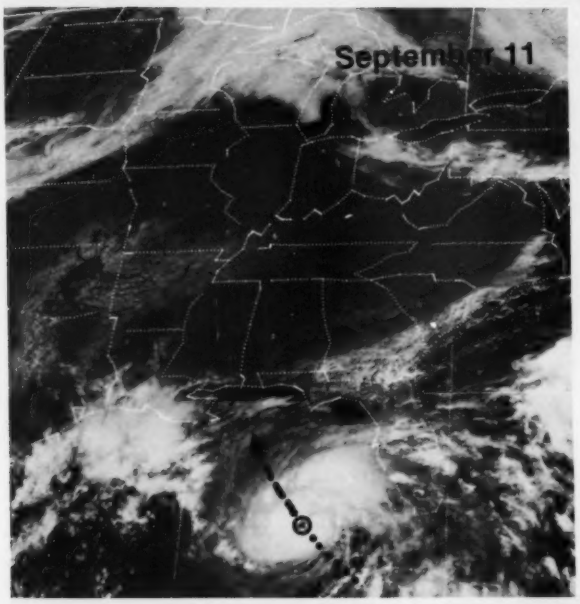






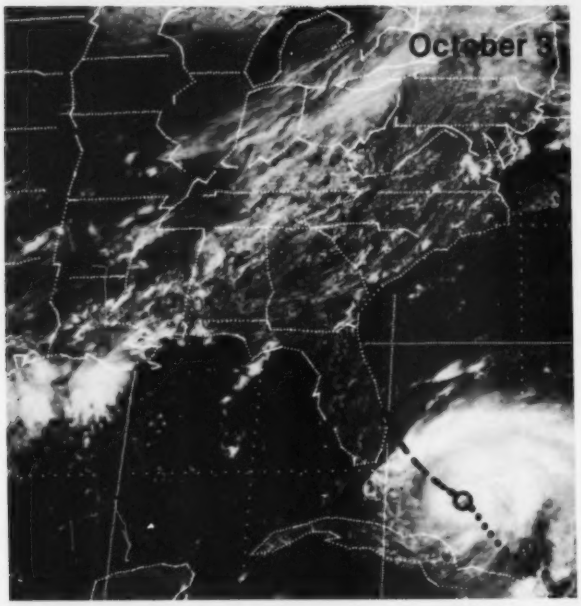
The end of last May, NOAA Administrator Richard A. Frank warned that "soon" a hurricane would hit U.S. shores, endangering lives and causing severe property damage. It took fewer than 100 days for his prophecy to become reality. On September 3, Hurricane David feinted at Miami, bounced on and off shore up the Florida east coast, and finally went inland near Savannah, Ga. Nine days later, Hurricane Frederic smashed ashore out of the Gulf of Mexico into Mobile, Ala.

Property damage from these two hurricanes was indeed severe. And lives were endangered. But due to the excellence of the forecasting and



View From Space

Hurricane Frederic pushed huge piles of sand over the roadway on Dauphine Island, Ala., which was directly in the path of the 130-mile-per-hour winds.



warning, as well as of the pre-disaster preparedness efforts of NOAA's National Weather Service, only seven deaths in the continental United States have been attributed to the storms.

These pages show views of both storms as seen from NOAA's East Coast GOES satellite.

Lifesaving dash caps scientific cruise

On The Edge Of The Arctic Ice

By RICHARD E. NEWELL

Ice. It is the single most important feature of the Arctic marine environment. It is a barren lid on the polar seas, a giant reflector of sunlight and heat, a suppressor of waves, currents, and tides. And it is a mighty barrier to ships seeking the oil and mineral wealth of the far north.

The edge of the ice pack abounds with life. On the rim, in the nutrient-rich waters of the Bering Sea, birds and seals congregate in droves to feed on fish drawn to the ice by the region's earliest bloom of microscopic plants. Indeed, the waters of the Bering continental shelf contain some of the largest fish, crab, and marine mammal stocks in the world.

Pooled beneath the shelf, geophysicists suspect, in oil—not just beneath the Bering, but also under the far-flung shallows of the Chukchi to the north and the Beaufort bordering Alaska's north slope.

Before the exploratory rigs go up offshore, scientists need to identify the parts of wildlife ecosystem and probe the dynamics of the food web. As was necessary before parts of Alaska's southern coast were opened up for development, researchers have to understand the workings of the "oceanographic engine" driving the ecological system—understand it well enough, for instance, to predict the effects of an oil spill on life at the edge of the ice pack.

One of the most recent scientific forays into the pack took investigators to the Chukchi and northern Bering Seas, the least studied of the waters off Alaska. The U.S. Coast Guard icebreaker *Polar Sea*, out of Seattle, played host to eight Federal and university researchers of an early spring cruise in 1979. It was the scientists' first chance to study the region at a time of year when ice up to eight feet thick and ridges four times thicker keep conventional research vessels away.

Temporarily alone in the vast whiteness, a solitary scientist cores for ice samples.

Staffers from NOAA's Outer Continental Shelf Environmental Assessment Program (OCSEAP) were aboard to investigate the food web in those waters. They were funded by the Interior Department's Bureau of Land Management, which has the job of predicting whether the marine environment can withstand the pressures of oil and gas development.

Ice-edge productivity, long appreciated but not well understood, is tied to the sea's food cycle. At the base of the food web are plankton, microscopic organisms that drift with the currents. Some of them, together with dead marine animals and waste material, sink to the lower layers of the sea, where bacteria decompose them. The resulting nutrients remain trapped in the cold depths, except in the 10 percent of the global oceans where active upwelling occurs.

Upwelling waters renourish the surface layer, but deep mixing limits the plants and nutrients there to only periodic sunlight. At high latitudes this exposure increases dramatically when the spring sun warms the ocean surface. Plants in the sunlit zone feed, grow, and multiply in a population explosion called the "spring bloom."

In the Bering Sea the growth season begins with three blooms, two of which are ice-related. The first bursts of life each year, they make the Bering the prolific area it is.

The first growth takes place at the base of the ice pack. Nutrients are continually present there, as the ice lid keeps water circulating between the rich bed of the continental shelf and the base of the pack. With the ending of winter, solar radiation increases, the snow cover melts, and more light reaches the dim lower levels.

Ice algae, having lived on the bed of the shelf since the previous spring icemelt, respond to the brightening overhead by riding the water current upward to the ice pack in late February. Lodging in the lowest few centimeters, with abundant nutrients and steadily increasing light, they produce a thick brown coating on the undersurface. This builds to a maximum just before the ice melts, a seasonal harvest for small fish such as herring.

The other ice-related plant bloom is more closely related to the familiar open-water spring bloom. Sea-ice

salt collects in tiny pockets of brine that gradually sink through the ice block. In the spring, as the sea surface warms and the pack begins to melt, the melted water—less dense than sea water—forms a shallow, stable layer quickly, much sooner than that produced by the spring heating in open waters to the north.

Beginning in April, this spring bloom follows the retreating ice edge northward through early summer, back to its permanent polar home. The phytoplankton trapped in these bright food-rich waters combine with algae under the ice, making the edge of the pack a cold-water oasis for the millions of fish, birds, and mammals that swim, swoop, and cavort there.

On April 15, as the ice-edge bloom began its annual northward migration, the *Polar Sea* stood locked in pack ice off the city of Nome. Chief Scientist of the six-member research party who crossed the snow-covered Bering Sea ice to board the ship on that misty morning was Dr. David Nyquist, an ecologist from OCSEAP headquarters in Boulder. With him were college students Sheila Finch of NOAA's cooperative student program and scientists from the University of Washington, Seattle, and the University of Louisville, Ky.

Two marine engineers under contract to the Maritime Administration also boarded the ship. They had come to gather ship performance data for possible use in the development of a year-round marine transportation system serving northwestern Alaska.

The *Polar Sea* departed three days later, bound for Bering Strait, gateway to the Arctic Ocean. The new 122-meter (399-foot) ship cut easily through the ice. It was a smooth ride, but noisy—the scrape of steel hull against thick sea ice producing a deep, deafening roar. "It's like putting an empty tin can to your ear and rubbing it with a

Guy Richter deploys bongo nets to collect zooplankton near the ice pack.

rock," said a young Coast Guard officer.

It's a brute force approach to breaking ice, but the *Polar Sea's* bow was designed for it, combining the forward motion of the ship with the downward pull of gravity as the ship rides onto the ice. First, the sharp bow makes a crack that extends several feet ahead. Then the broad, curved hull pushes downward on either side of the crack, breaking off large cakes of the ice that are stood on edge, pushed aside, and left floating astern. The channel often refreezes within minutes.

When the ship stopped to lower a sampling device into the water, the scientists and survey technicians faced a problem familiar to the walrus, the seal, and the whale—breaking open a "breathing hole" and keeping it open. "Getting equipment down through the pack and back up again without damage was a real problem," said Nyquist, "but we managed it by using a fire hose to blast a hole in the ice."

Another problem was working at night, in high winds. "Handling a big, heavy dredge on a wet, rolling deck has its hazards," said Nyquist. "Icebreakers aren't really designed for this type of work, but we couldn't have obtained our samples any other way."

On her flight deck aft, the ship carried two high-speed amphibious helicopters to survey ice conditions and spot open water. Scientists also turned them to scientific uses as observation platforms for counting and observing birds and marine mammals. During the first phase of the cruise they flew low along the Siberian coast in the west Bering Sea, seeking the endangered bowhead, another creature of the ice edge.

The ship passed through the Bering Strait four days out of Nome. Bounded by the bold headlands of Cape Dezhneva on the west and Cape Prince of Wales on the east, the Strait is the narrowest place of contact and exchange between any two of the world oceans. Here Pacific water, often hidden beneath several feet of ice, rushes into the Arctic Ocean over a narrow, shallow sill just 85 kilometers (53 miles) wide and 50 meters (164 feet) deep. This wind-driven flow draws nutrient-rich water northward and upward from the depths of the Pacific to the Bering shelf.

Long before the earliest seafaring explorers, when the top several hundred feet of the ocean were locked up in Ice Age polar caps, the sill became the crest of the "Bering Strait Bridge," the land link between the old world and the new—an east-west passageway for herds of pygmy mammoths, giant ground sloths, oversized bison, and eventually aboriginal man.

A few hours' travel beyond the Strait found the *Polar Sea* at the Arctic Circle, on April 22, two months before the midnight sun. Transiting this part of the globe, like crossing the equator of the International Date Line, is cause for celebration. In the tradition of all American military ships, the lowly "Bluenoses" aboard were subjected to a day-long secret ceremony from which they emerged exalted "Polar Bears."

After the brief venture into the Chukchi Sea, the ship headed back south through the Strait, occasionally stopping to probe the ice along the way. The going was slow, against stiff winds and currents and nighttime visibility of only 275 meters (300 yards) in blowing snow. "A couple of nights we actually logged a minus two or three nautical miles," Nyquist said.

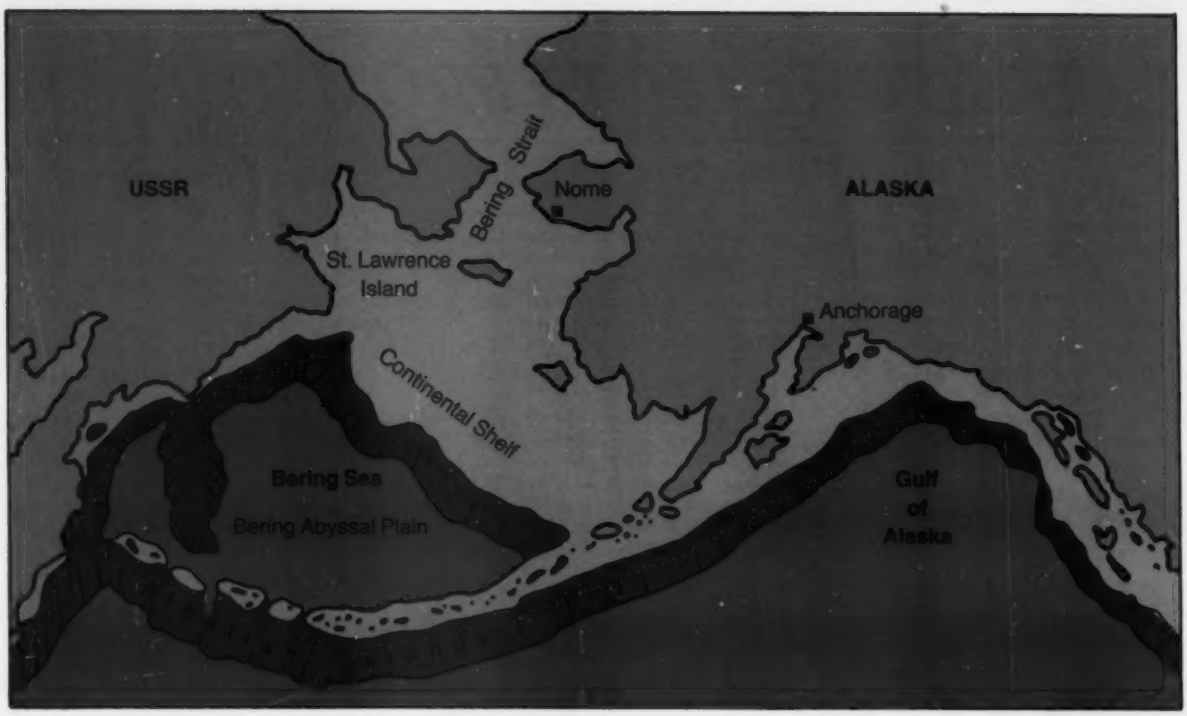
On April 27, with a record-breaking 4,000 nautical miles of ice navigation behind her, the *Polar Sea* left the pack, pausing only long enough to sample the ice edge. As with most of this cruise's measurements, analysis would await the return home.

But the next day, as the ship steamed south across the Bering shelf, the radio operator received an urgent message—a group of Eskimo hunters was in danger, stranded on an ice floe to the north.

The ship turned back into the ice pack, switching from diesels to full turbine mode, the course set for St. Lawrence Island.

The land mass of St. Lawrence Island dominates the northern Bering Sea. Hunters had set out the after-

Search-and-rescue mission saves 13 stranded Eskimo hunters.



noon before from Savoonga, a small village on the island's north coast. They traveled in small boats over the open waters in the lee of the island, out to the ice pack. There, they knew they would find walrus.

As in generations past, these Eskimos depend on the walrus for its thick hide, abundant meat and oil, and great ivory tusks. Both they and ecologists are worried that the soaring walrus population may be outstripping the food supply. The animals numbered about 200,000 in 1975, more than at any time since the mid-1800's, and there are increasing reports of very lean animals. St. Lawrence islanders fear that the population is about to "crash," just as the island's reindeer herd did in 1948, when food scarcity cut its numbers from 10,000 head to 100 in less than a year.

These worries did not dampen the spirit of the hunt for the 11-year-old Eskimo boy Arthur Gologergen, late that afternoon as the boats motored north from Savoonga. It was exciting. By sundown he had killed his first walrus. Then the south wind sprang up, the ice began to shift, darkness fell, and Arthur, along with 12 adults, became separated from the rest of the party.

They tried to fight the headwind back to the island, but ran out of gas. Those who did passed word to the Alaska state troopers in Nome, who relayed it to the Coast Guard at Kodiak.

The *Polar Sea* found the group huddled in their boats on an ice floe 25 miles north of the island. The floe was awash in 16-foot seas, kicked up by winds gusting to 55 knots. One of the helicopters, piloted by Lt. Grant Leber, ferried the stranded hunters to the ship. In spite of marginal flight conditions, Leber managed to hold his craft less than a foot above the ice floe, so that the freezing villagers could step aboard.

"They couldn't have survived another three or four hours," said Nyquist. "They were entering the first stages of hypothermia. One of them shook for two hours after coming in out of the cold."

After cruising back to St. Lawrence Island on the biggest ship he had ever seen, Arthur had his second helicopter ride, into the middle of the village, where families and friends greeted the hunters.

The *Polar Sea* rounded the island and steamed southward. She had plucked 13 Eskimo hunters from certain death. Would the results of her ice-edge research help preserve their dynamic but vulnerable ecosystem? She had burned 41,000 gallons of fuel in her 9-hour dash through the pack. Would her ice-breaking studies help bring bigger ships to that region?

This research cruise was just a beginning, but an auspicious one. To the townspeople of Savoonga, one of the first of the "big ships" to enter their lives had saved the day. Whether or not Arthur knows it, the purpose of this ongoing research is to continue to protect his corner of the marine environment from harm while serving the energy needs of the Nation.

GUSTATORY GEMS FROM THE SEA

A treasured recipe is one that quickly and easily prepared without sacrificing flavor and appeal. Fish recipes are especially good since fish cook quickly, are nutritious, and readily available, fresh or frozen. For the novice cook or busy cooks with an eye on the clock, we present this treasure of seafood recipes.

SALMON ALASKA

1 can (1 pound) salmon
1 cup mayonnaise or salad dressing
2 tablespoons lemon juice
1½ teaspoons parsley flakes
Dash cayenne pepper
2 egg whites
6 tomato slices
6 slices white bread, toasted

Drain salmon. Remove the skin and bones. Flake the salmon. Combine mayonnaise, lemon juice, parsley, and pepper. Beat egg whites until stiff but not dry. Fold mayonnaise mixture into egg white. Place a tomato slice on each piece of toast. Cover tomato with salmon. Place sandwiches on a bake and serve platter, 16 x 10 inches. Spoon mayonnaise mixture over each sandwich. Broil about 12 inches from source of heat for 6 to 8 minutes or until lightly browned. Makes 6 servings.

TROUT ORIENTALE

2 cans (6½ or 7 ounces each) tuna
½ cup chopped green onion
¼ cup salad oil
4 cups cold unsalted cooked rice
3 tablespoons soy sauce
2 eggs, beaten
1 can (5 ounces) water chestnuts, drained and chopped

Drain and flake tuna. Cook onion in hot oil in a 10"- fry pan until tender. Add rice and soy sauce. Stir over low heat until rice is hot. Push rice to one side. Pour in egg and cook, stirring frequently. Add water chestnuts and tuna. Mix well and heat. Makes 6 servings.

FAST FISH BROIL

2 pounds skinless catfish fillets or other fish fillets, fresh or frozen
¼ cup garlic French dressing
3 tablespoons soy sauce
¾ teaspoon ground ginger
Lime slices

Thaw frozen fillets. Place fillets in a single layer, skinned side down, on a bake and serve platter, 16 x 10 inches. Combine French dressing, soy sauce, and ginger. Pour sauce over fillets and let stand 10 minutes. Broil about 4 inches from source of heat for 10 to 15 minutes or until fillets flake easily when tested with a fork. Baste once during broiling with sauce in pan. Garnish with lime slices. Makes 6 servings.

DILL TROUT

2 pounds pan-dressed trout or other small pan-dressed fish, fresh or frozen
1½ teaspoons salt
¼ teaspoon pepper
½ cup butter or margarine
2 teaspoons dill weed
3 tablespoons lemon juice

Thaw frozen fish. Clean, wash, and dry fish. Cut fish almost through lengthwise and spread open. Sprinkle with salt and pepper. Melt butter in a 10-inch fry pan. Add dill weed. Place fish in a single layer, flesh side down, in the hot dill butter. Fry at moderate heat for 2 to 3 minutes. Turn carefully. Fry 2 to 3 minutes longer or until fish flake easily when tested with a fork. Place fish on a warm serving platter. Keep warm. When all the fish have been fried, turn heat very low and stir in lemon juice. Pour sauce over fish. Makes 6 servings.

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NOAA Magazine
Washington, D.C. 20402

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